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(71) Applicant (for all designated States except US): MICRO-GEN ENERGY LIMITED [GB/GB]; 100 Thames Valley Park Drive, Reading, Berkshire RG6 1PT (GB).

(72) Inventors; and

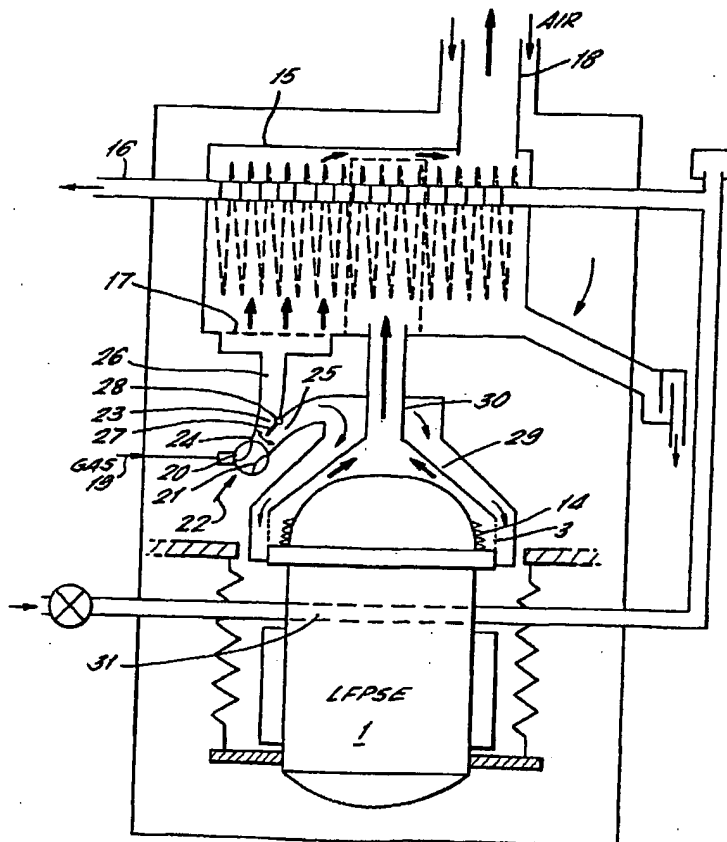
(75) Inventors/Applicants (for US only): CLARK, David, Anthony [GB/GB]; 4 Mill Dam, Hugglescote, Leicestershire LE67 2BU (GB). LOWRIE, James, Robert [GB/GB]; 6 Midland Place, Derby, Derbyshire DE1 2RR (GB). ALLDERIDGE, Heather [GB/GB]; 51 Derby Road, Aston-on-Trent, Derby, Derbyshire DE72 2AE (GB).

(74) Agents: DRAPER, Martyn, John et al.; Boulton Watt Tennant, Verulam Gardens, 70 Gray's Inn Road, London WC1X 8BT (GB).

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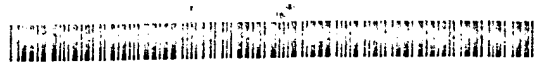
[Continued on next page]

(54) Title: A HEATING APPLIANCE



(57) Abstract: A domestic combined heat and power system comprising a Stirling engine (1) and water heater in the form of a supplementary burner (17). The exhaust gas from the Stirling engine is used to preheat combustible gas entering the Stirling engine and subsequently used to heat the water. The water heater (15) has a helical water duct (41) towards the periphery of a housing (39). Separate parts of this duct are heated, in series, by the exhaust gas from the Stirling engine and the supplementary burner (17) firing radially outwardly through the helical duct.

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**Declaration under Rule 4.17:**

- of inventorship (Rule 4.17(iv)) for US only

A HEATING APPLIANCE

The present invention relates to a heating appliance. In particular, the invention relates to  
5 a domestic combined heat and power (DCHP) unit.

Such DCHP units have been proposed which incorporate a Stirling engine connected to an alternator to generate electricity. The heat  
10 produced by the engine which would otherwise be wasted is used to heat water feeding the domestic water and central heating systems, and therefore becomes a valuable product of the DCHP system. It has been shown that the most favourable economics  
15 are achieved for the unit when the Stirling engine/alternator is sized to generate approximately 1kW of electricity. At this level, however, only approximately 5kW of heat will be provided, which is substantially below a typical domestic heat load of  
20 in excess of 20kW.

In order to supply the remaining heat, so that the DCHP unit can compete effectively with the current specification of a domestic boiler, a  
25 supplementary gas burner is required. The present invention aims to provide a thermally efficient operation of the Stirling engine and supplementary burner.

30 According to the present invention there is provided a domestic combined heat and power assembly comprising a Stirling engine and a water heater wherein the Stirling engine is arranged to be heated by a first burner fed with combustible gas, the  
35 assembly further comprising an exhaust gas duct

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passing from the Stirling engine in contact with a  
combustible gas inlet into the first burner to  
preheat the combustible gas entering the first  
burner and subsequently heat water which is  
5 additionally heated by the water heater.

Thus, heat from the exhaust is initially  
recovered into the incoming air/gas mixture to the  
burner which has the effect of reducing the fuel to  
10 be burned and increasing combustion temperature  
which increases the rate of heat transfer to the  
Stirling engine and hence improves the efficiency of  
the system. This exhaust gas which has now cooled  
to some degree is then used to heat the water which  
15 is also heated by the supplementary water heater,  
thereby reducing the thermal input required from the  
supplementary water heater.

An increase in efficiency is obtained if the  
20 system is arranged to heat the water with the  
exhaust gas upstream of the water heater.

The supplementary water heater may, for  
example, be an electric heater, but is most  
25 preferably a supplementary burner.

Preferably the system is arranged so that the  
exhaust gas and gas from the supplementary burner  
form a combined stream once they have given up heat  
30 to the water and the combined stream is arranged to  
heat the water upstream of the exhaust gas. With  
such an arrangement, the water will receive  
relatively low grade heat from the combined stream,  
as the components of the combined stream have  
35 already given up some heat to the water. The water

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will then subsequently receive relatively higher grade heat directly from the exhaust gas and from the supplementary burner. Such an arrangement is thermally efficient.

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Preferably the system further comprises a Stirling engine cooler arranged to heat the water upstream of the exhaust gas heating. This not only serves to promote the heating of the water, but also helps to maintain the required temperature differential across the Stirling engine.

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Alternatively, the invention may be defined as a method of operating a domestic combined heat and power assembly, comprising supplying heat from a first burner to a Stirling engine, exchanging heat from an exhaust gas stream leaving the Stirling engine with a flow of combustible gas feeding the first burner, and subsequently exchanging heat from the exhaust passing from the first burner with water, and further heating the preheated water in a water heater.

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The burner gases heating the head of the Stirling engine are typically at around 1400°C. As the gases flow around the head, heat is transferred into the heater head, and the temperature of the gases falls to around 800°C. The gases transfer heat to the incoming fuel/air mixture. If there is no further heat recovery, the exhaust gases flowing into the Stirling engine flue then typically have a temperature of around 600°C.

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The present invention also extends to a novel design of heating arrangement to transfer heat into

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the water. The requirements for this are that it is compact and is able to transfer heat from at least two streams into the water at maximum efficiency.

5           According to a further aspect of the present invention there is provided a heating arrangement for heating a fluid, the arrangement comprising a housing; a duct within the housing towards its outer periphery and helically wound about a central axis  
10       of the housing to convey the fluid from the first end of the housing to a second end of the housing; a supplementary burner in the housing adjacent to the second end and surrounded by the duct to transfer heat to the fluid in a first portion of the duct; an  
15       outlet for hot gas from an external heat source, the inlet being configured to direct the hot gas radially outwardly onto a second portion of the duct closer to the first end of the housing than is the first portion of the duct.

20           Such an arrangement is particularly compact as the supplementary burner and inlet for gas from an external source are within the duct through which the fluid is conveyed. Further, the supplementary  
25       burner and inlet are arranged to transfer heat to different parts of the helical duct. Thus, the arrangement can be set up to be particularly thermally efficient.

30           Preferably the inlet is arranged to substantially prevent mixing of the gas from the supplementary burner and the hot gas from the external heat source at least until both have passed through the helically wound duct. Thus the streams  
35       are substantially prevented from mixing prior to

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reaching the duct ensuring a more efficient heat transfer.

5       Once the exhaust gas and hot gas from the  
external source have passed through the helically  
wound duct, they may then simply be discharged  
either separately or as a combined stream. However,  
preferably, the two streams are formed into a  
combined stream once they have initially given up  
10   some heat to the duct, and the combined stream is  
passed around a third portion of the duct closer to  
the first end than is the second portion of the  
duct. Thus, the cool fluid in the helically wound  
duct which enters the first end of the housing  
15   initially encounters this relatively cool combined  
stream and is preheated by this stream before being  
heated by the gas from the external heat source and  
the gas from the supplementary burner.

20       Although some mixing of the gas from the  
supplementary burner and the hot gas from the  
external heat source is tolerable as a small amount  
of mixing will have relatively little effect on the  
overall heating of the fluid, it is preferable to  
25   minimise such mixing as much as possible.  
Therefore, preferably, a seal is provided to prevent  
mixing of gas from the supplementary burner and the  
hot gas from the external source radially inwardly  
of the duct.

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In order to maximise the heat transfer to the  
duct, the duct is preferably arranged such that each  
coil of the duct is flattened in the direction of  
the central axis so that, in cross section, its  
35   radial dimension exceeds its axial dimension. Also,

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preferably, adjacent coils of the duct are closely adjacent to or abut one another. This ensures that the hot gas has to pass through a relatively long and narrow passageway between adjacent coils of the duct which makes for efficient heat transfer. This duct configuration is shown in WO 94/16272. ) J. G. Per

An example of the invention will now be described with reference to the accompanying drawings, in which:

Fig. 1 is a schematic diagram showing the layout of a first Stirling engine system;

Fig. 2 is a schematic diagram showing the layout of a second Stirling engine system;

Fig. 3 is a cross-section through a heating arrangement; and

Fig. 4 is an end view of the arrangement of Fig. 3.

The arrangement shown in Fig. 1 comprises a Stirling engine 1 to which heat is supplied by a burner 14. The heat is transferred to the head by a system of fins 3 as disclosed in our earlier co-pending application no. 0020012 and exits through a flue.

The arrangement in Fig. 1 has a water heater 15 which is arranged to heat a water stream 16 by virtue of a supplementary burner 17. Exhaust gases are expelled through flue 18.



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A common gas supply line 19 is provided for both the first 14 and supplementary 17 burners. This gas flow is controlled by a single multi-functional valve 20. The burner controls  
5 controlling ignition and flame detection of the burner may be incorporated into a multi-functional controller. Gas in the multi-functional valve 20 enters a mixing chamber in the form of a venturi manifold 21 and is mixed with an air stream 22  
10 driven by a fan.

The gas and air mixture is now supplied to a splitter valve 23 in which one inlet 24 leads to a first burner outlet 25 and a second burner outlet  
15 26. The relative amount of flow to each outlet is controlled by a flap valve 27 which is rotatable about an axis 28. The position of the flap valve 27 will be set by the appliance controller, and is driven to that position, for example, by a servo  
20 motor. Alternatively the air flow could be divided after a single intake fan 60, by such a splitter valve 23, and then each air stream could incorporate a multi-functional valve/controller to accurately meter the gas mixture to each burner. This  
25 arrangement is shown in Fig. 2.

The fuel/air mixture fed to the Stirling engine 1 flows around a cowling 29 enclosing the burner arrangement and is hence heated by the hot gas  
30 stream leaving the burner. The exhaust gas which has given up some of its heat to the incoming mixture leaves the cowling through manifold 30 and enters the water heater 15 where it comes into contact with the water stream 16 (which has already  
35 been heated to some extent in the Stirling engine

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cooler 31) so as to further preheat the water stream 16 upstream of the supplementary burner 17. The supplementary burner 17 is fired to provide supplementary heating to the water stream 16 if  
5 required. The exhaust gas from the first burner 14 leaves the water heater 15 with the exhaust gas from the supplementary burner 17 through flue 18.

The heating arrangement is shown in more detail  
10 in Figs. 3 and 4 and comprises the supplementary burner 17 and water heater 15. The water heater 15 has a generally cylindrical housing 39 with a main axis 40. The supplementary burner 17 is positioned on the axis 40 so as to fire radially outwardly.

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Water is fed through the water heater 15 from the right hand side of Fig. 3 to the left hand side around a water duct 41 which is a single helical tube (which may be made up of a number of connected  
20 segments) wound around the axis 40 towards the outer periphery of the cylindrical housing 39. Each individual coil of the water duct 41 is flattened in the axial direction. Adjacent coils are positioned closely adjacent to one another, but are not sealed  
25 together such that hot gas can pass between adjacent coils. Extending towards the middle of the heater 15 is an inlet 42 for the exhaust gas from the Stirling engine. The inlet leads to a circular chamber 43 defined between two circular plates  
30 44,45, the latter of which is an opening for the inlet 42. Annular brackets 46 bridge the gap between the edge of the plates 44,45 and the water duct 41 to ensure that all the exhaust gas from chamber 43 passes through the coils of the water  
35 duct 41. Towards the second end from the chamber 43

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is a supplementary burner chamber 47 into which the supplementary burner 17 fires. The supplementary burner heats the adjacent coils towards the second end.

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Towards the first end from the chamber 43 is a discharge chamber 48 with an outlet 49. There is also an outlet 50 for condensate produced due to the high efficiency nature of this final stage of heat recovery.

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The operation of the water heater 15 is as follows. Water flows through the water duct 41 from the first end to the second end around a helical path. The supplementary burner 17 fires into chamber 47 and exhaust gas enters at inlet 42 and passes into chamber 43. These two hot streams pass radially through gaps between adjacent coils in the water duct 41 into an outer annular chamber 51 and form a combined stream. This combined stream then flows back through the water duct 41 adjacent to the first end as indicated by arrow 52. The incoming water is therefore initially heated by this combined stream. As it flows further towards the second end it encounters the Stirling engine exhaust gas from the chamber 43 and is heated further. Finally, it encounters the hot gas from the supplementary burner 17 to provide a third stage heating.

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By providing this three stage heating arrangement, efficient heating of the water is provided. Further, as can be appreciated from Fig. 2, the arrangement in which this three stage heating is provided is particularly compact resulting in cost and space saving.

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**CLAIMS**

1. A domestic combined heat and power system comprising a Stirling engine and a water heater,  
5 wherein the Stirling engine is arranged to be heated by a first burner fed with a combustible gas, the assembly further comprising an exhaust gas duct passing from the Stirling engine in contact with a combustible gas inlet into the first burner to  
10 preheat combustible gas entering the first burner, and subsequently heat water which is additionally heated by the water heater.
2. A system according to claim 1, wherein the  
15 system is arranged to heat the water with the exhaust gas upstream of the water heater.
3. A system according to claim 1 or claim 2,  
20 wherein the supplementary water heater is a second burner.
4. A system according to claims 2 and 3, wherein the system is arranged so that the exhaust gas and gas from the supplementary burner form a combined  
25 stream once they have given up heat to the water and the combined stream is arranged to heat the water upstream of the exhaust gas.
5. A system according to any one of the preceding  
30 claims, further comprising a Stirling engine cooler arranged to heat the water upstream of the exhaust gas heating.
6. A method of operating a domestic combined heat  
35 and power assembly, comprising supplying heat from a

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first burner to a Stirling engine, exchanging heat from an exhaust gas stream leaving the Stirling engine with a flow of combustible gas feeding the first burner, and subsequently exchanging heat from the exhaust passing from the first burner with water, and further heating the preheated water in a water heater.

7. A heating arrangement for heating a fluid, the arrangement comprising a housing; a duct within the housing towards its outer periphery and helically wound about a central axis of the housing to convey the fluid from the first end of the housing to a second end of the housing; a supplementary burner in the housing adjacent to the second end and surrounded by the duct to transfer heat to the fluid in a first portion of the duct; an inlet for hot gas from an external heat source, the inlet being configured to direct the hot gas radially outwardly onto a second portion of the duct closer to the first end of the housing than is the first portion of the duct.

8. An arrangement according to claim 7, wherein the inlet is arranged to substantially prevent mixing of the gas from the supplementary burner and the hot gas from the external heat source at least until both have passed through the helically wound duct.

9. An arrangement according to claim 7 or claim 8, wherein the two streams are formed into a combined stream once they have initially given up some heat to the duct, and the combined stream is passed around a third portion of the duct closer to the

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first end than is the second portion of the duct.

10. An arrangement according to claim 8, wherein a seal is provided to prevent mixing of gas from the supplementary burner and the hot gas from the external source radially inwardly of the duct.

11. An arrangement according to any one of claims 7 to 10, wherein each coil of the duct is flattened in the direction of the central axis so that, in cross section, its radial dimension exceeds its axial dimension.

12. An arrangement according to any one of claims 7 to 11, wherein adjacent coils of the duct are closely adjacent to or abut one another.

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FIG. 1.

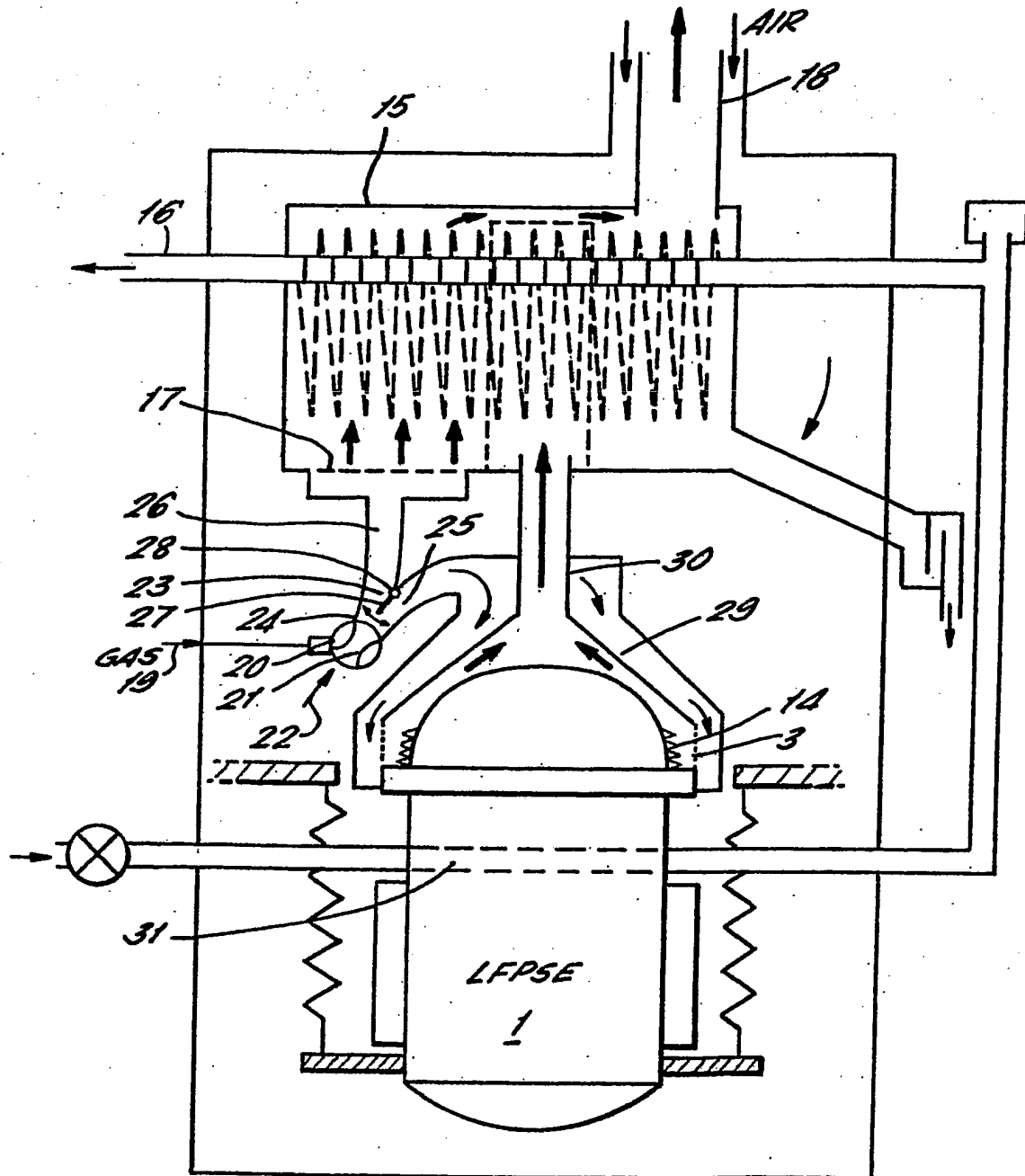
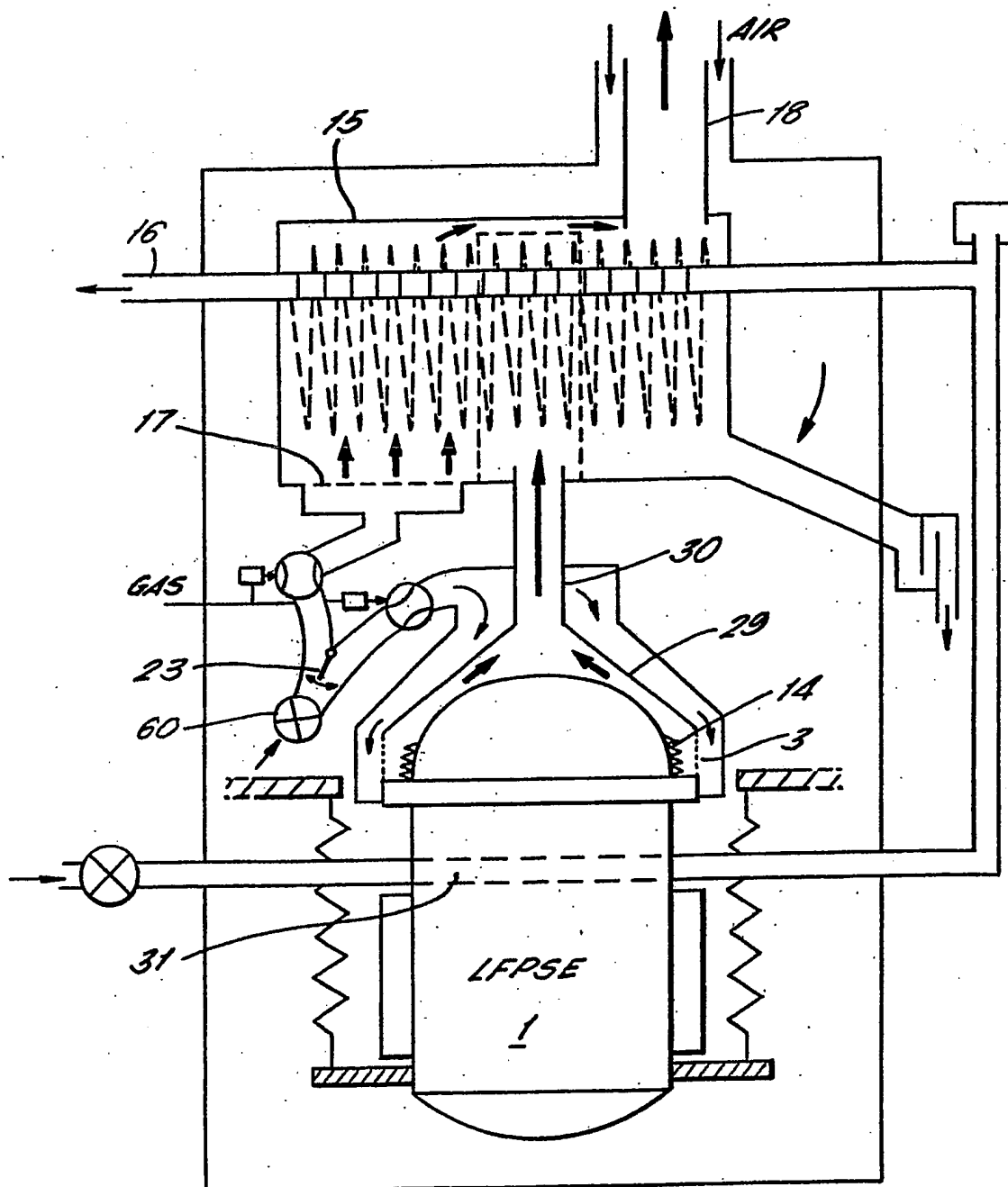
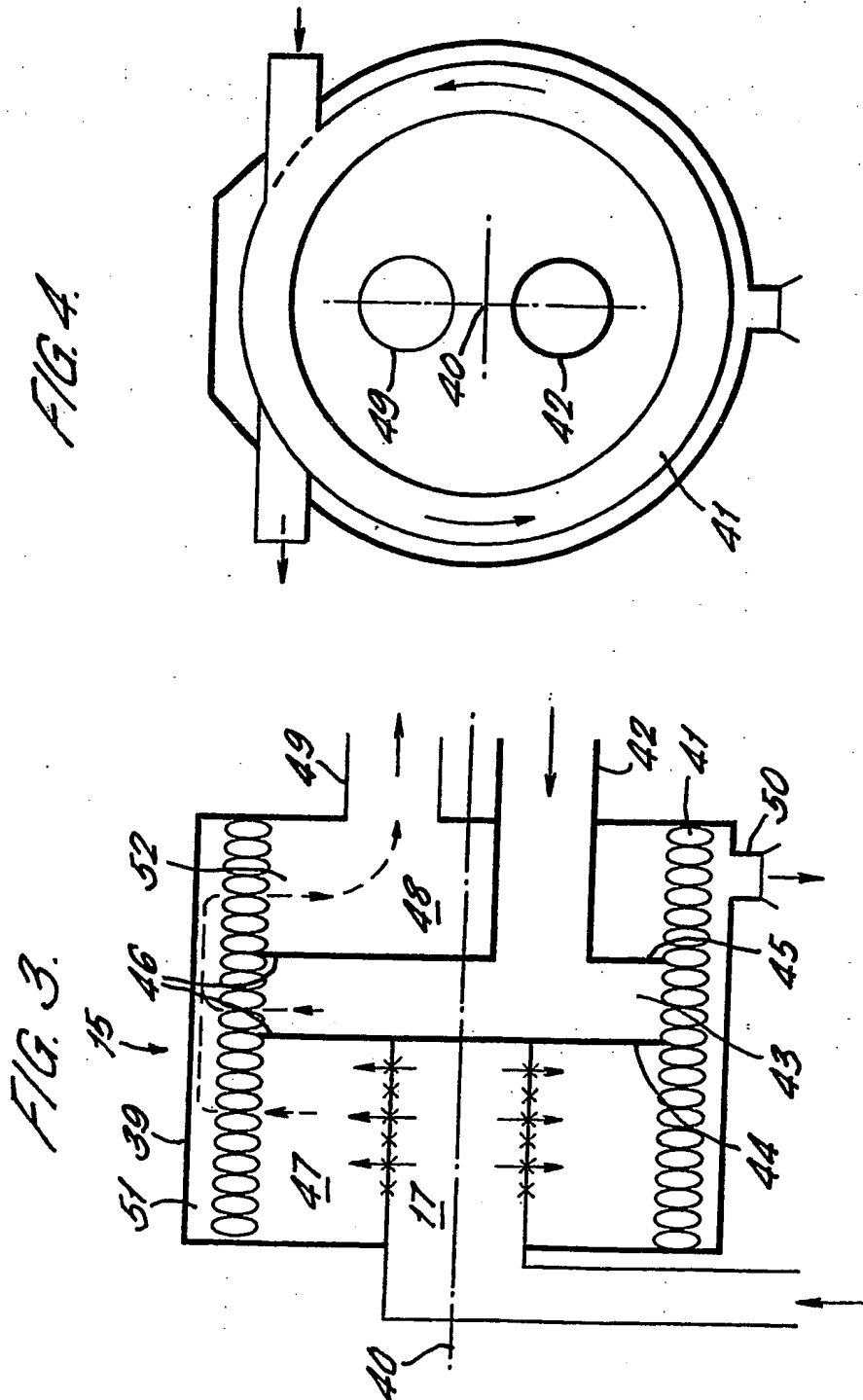


FIG. 2.







## INTERNATIONAL SEARCH REPORT

PCT/GB 02/05771

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 F24H1/00 F02G5/02 F02G1/055 F23L15/04 F28D7/02

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F24H F02G F23L F28D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No. |
|------------|---|-----------------------|
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| Y          | EP 0 445 510 A (MESSERSCHMITT BOELKOW BLOHM) 11 September 1991 (1991-09-11)<br>figure 1<br>column 3, line 57 - column 4, line 56                  | 1,2                   |
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| A          | column 2, line 5 - line 39<br>-/--  | 7,8,10,<br>12         |



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

## \* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"G" document member of the same patent family

Date of the actual completion of the international search

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European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Mougey, M

## INTERNATIONAL SEARCH REPORT

PCT/GB 02/05771

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages  | Relevant to claim No. |
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PCT/GB 02/05771

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# INTERNATIONAL SEARCH REPORT

PCT/GB 02/05771

## Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
  
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
  
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
  
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
  
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☒ No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

International Application No. PCT/GB 02 05771

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-6

Cogeneration system including a stirling engine and a water heater

2. Claims: 7-12

Device to heat a fluid using a burner, an external heat source and a heat exchanger